ISSN:1687-1006

The Egyptian International Journal of Engineering Sciences and Technology

Vol. 32 (2020) 59–65

https://eijest.journals.ekb.eg/

An Intelligent Warehouse Management System Using the Internet of Things

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ARTICLE INFO

Keywords:

1st Internet of Things
2nd Warehouse Management System
3rd Supply Chain

ABSTRACT

Nowadays, the warehouse acts as a competitive factor in any supply chain as it has a main role in linking all the partners in it. Hence, it has become very necessary to allocate its resources efficiently and manage it effectively. A sound warehouse management system can contribute to cost reduction and improve customer satisfaction. However, traditional warehouse management system models have become unsuitable and inefficient for today's market requirements. So, companies have started to adopt innovative approaches and technologies to be used for such applications; one of these technologies is the Internet of Things that enables the connection between several physical objects and produces a massive amount of real-time data that can be transferred to useful information that helps in managing and decision making. In this paper, the architecture of this application is illustrated, its potential benefits are overviewed, and a framework for implementing this technology in a warehouse is proposed. This system can help in achieving more control and monitoring on all the operations in the warehouse in real time, increase speed and efficiency, and prevent counterfeiting and inventory shortage. The proposed framework can be taken as a roadmap for enterprises to improve warehouses by using the Internet of Things. Also, the benefits of implementing the proposed framework and its challenges are proposed.

1. Introduction

Supply chain is consisted of all the processes, transformations and flows that are involved in producing a product from raw material to the finished product. "The supply chain consists of all parties involved directly or indirectly in fulfilling a customer request. The supply chain includes not only the manufacturer and suppliers, but also transporters, warehouses, retailers and even customers themselves" [1]. Supply Chain Management (SCM) aims to meet customer requirements on time with the highest quality and lowest cost that can be obtained by improving the process and achieving the linkage between them, removing non-value added activities across the supply chain and make the supply chain more agile [2].

WMS is used for optimizing warehousing decisions by integrating many software systems that can monitor, manage and control anything in the warehouse [3]. ERP and APS systems are the most popular systems used in warehouses. Nowadays these systems cannot face the supply chain challenges such as agility, flexibility and responsiveness [4]. Traditional WMSs are become not able to face today's market challenges, enterprises now in need to be more flexible and creative. Adapting IoT help enterprises to face these challenges as it provides more flexibility and hence, improves the all performance of the enterprises.

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IoT make every object talk to each other through the internet by using many technologies. These technologies can be used in tracking, tracing, monitoring and control. That can produce a massive amount of data that could be transferred to useful information [5].

IoT can help in optimizing demand forecasting, making an intelligent transportation system, and creating an intelligent warehouse management system.

In this paper, section 2 presented a review about how adapting WMS impact on supply chain and also how information sharing and implementing IoT in the warehouse impact on it. Section 3 illustrates IoT architecture and its building blocks. In section 4 the impact of using IoT in supply chain, a framework structure of using IoT in warehousing and the expected benefits and challenged are presented. At the end a conclusion are presented in section 5.

2. Literature review

2.1. How Adapting Warehouse Management System Impacts on Supply Chains

Adopting WMS have a positive impact on the supply chain performance, for example, using Management Information System (MIS) and wireless barcodes can achieve cost reduction, flexibility, inventory reduction, and delivery time reduction, thus achieve customer satisfaction [6].

In [7], a framework based on RFID is proposed to track work-in-progress, track inventory, and improve picking and receiving goods in a wool yarn industry. In [8], the problem of inaccurate inventory was studied that resulted from the bullwhip effect through the supply chain; the authors have studied the impact of applying RFID on this problem and found that utilizing RFID in the upstream stages is less beneficial and efficient compared to when utilizing in the downstream stages. In [9], the barcode management application is used and discussed for the WMS of a pharmaceutical enterprise; the authors found that it helps in managing inventory, support decision making and decrease workforce costs, thus achieves improved overall performance. [10] Presented a case study for digital WMS using RFID in tobacco industry, they founded that adapting RFID help in achieving more inventory control, increasing efficiency of the operations, enhancing warehouse utilization, reducing manpower, reducing loading time and increasing inventory accuracy. According to [11] supply chains are facing unprecedented challenges and they need to be more dynamic. The logisticians need to be more creative and flexible to help enterprises in facing these challenges. The five factors of future logistics are presented (automation, economic sustainability, ecological sustainability, individualization and social sustainability) and the authors illustrated how industry 4.0, cloud computing and e-commerce help enterprises to overcome these challenges. [12] Argued that traditional WMS cannot meet today's challenges of market because of its low efficiency. The author presented a study of a smart WMS based on IoT and he founded that adapting IoT has a great impacts on the warehouses as it helps in improving the speed of the storage, reducing numbers of manual labors, simplifying the processes of inventory, reducing error rate and costs and improving the efficiency of the warehouse.

2.2. How Information Sharing and the use of IoT impact on demand forecasting and Supply Chain

In [13], the role of sharing information and is studied with showing its impact on transportation activities. It was found that, it has a great role in increasing the transport efficiency, improving transport quality, optimizing the driver's performance and decreasing transportation costs. In [14], a study was presented to know the impact of information sharing on the supply chain; the authors found that information sharing across the supply chain is essential but not enough and to make a significant improvement over the supply chain, there should be more focus on strengthening the internal integration and cooperation between partners and building the relationships on trust between them by achieving tasks together.

In [15], the authors studied the effect of using some applications of IT such as business intelligence on the supply chain by proposing a hypothetical model. The two dimensions that were taken into consideration were competitive advantage for resource-based view and service quality for market-based view. The authors found that although many techniques, such as RFID, were recommended by several researchers; most of enterprises do not realize the value of it. The hypothetical model presented can be considered as a roadmap for LSPs for improving their competitiveness. In [16], a simulation model was developed to study the impact of participating information about planning on inventory capital. The information was; point-of-sales data, customer forecasts, stock-on-hand and planned order data. They used the re-order point methods and found that the stock-on hand data has high value when the demand is stationary. Demand forecast data and planned order data have high value when the demand

is not stationary, and sharing point-of sales data has no value whether the demand is stationary or not.
All organizations seek to achieve competitive advantage and this can be reached when it understand customer needs. Enterprises do this through forecasting methods. [17] presented an overall view about forecasting and discussed the two methods of it (qualitative and quantitative), the authors argued that the data has a critical role in the two methods so it must be collected carefully with minimum error that can be obtained using IoT as it provides a real- time data that help in doing more accurate demand forecast. [18] Presented a conceptual framework to study the impact of IoT on the warehouse and founded that it; because of the availability of the accurate data that generated from IoT system, the enterprises can improve their forecast and managers can take more accurate decision that help in improving the company's' performance and make more profit. [19] Presented an interface implementation for monitoring and controlling warehouse using IoT, the authers argued that the device has a great role in monitoring products location and the wireless sensors help in controlling the environmental conditions such as temperature and humidity. Thus, make warehouse more efficient, reduce costs and increase the quality of materials. [20, 21, 22] confirmed that applying IoT in inventory, warehousing operations and logistics has a major and a great impact on the warehouse. It help in aking warehouse more efficient as it help in tracking and managing information of the warehouse, tracing everything in it, reducing manpower, increasing the efficiency of warehouse operations, reducing costs and improving the performance of the organization.

[23] Presented an IoT quality inventory management model for enterprises that called IIOT. The model illustrated how item in the warehouse can be easily identified and managed itself using IoT. The author argued that the proposed model can be used for automation and demand forecasting as it provides more accurate information that help in managing enterprise's functions easily, reducing costs and make enterprises more efficient.
Since the evolution of IoT, the researchers have studied and explored the using and impacts of implementing this technology in several fields. But, few researches showed its implementation in the field of SCM. In [24], the authors investigated the role of industry 4.0 factors on the service and production sectors in a texile industry in Pakistan through a survey questionnaire that collected data from managers. The factors are b-g data, cyber-physical system (CPS), smart factory, IoT and interoperability. The author found that these factors have a significant positive impact on the service and production sectors and they help in improving the overall performance of them.

In [25], an IoT-based model was proposed to solve the imperfect sharing of information problem using RFID, and two methods of information inquiry were introduced for dynamic and static information. The methods introduced help in tracing, tracking, and inspecting products at any stage anytime, hence improving quality, authenticity and increasing the efficiency of the supply chain. In [26], a framework was proposed to illustrate how to improve SCM performance by using IoT, especially supply chain innovation (SCI) using the integration between resources, activities and processes that help in improving the overall performance of all the supply chain partners.

3. About IoT Architecture

The architecture of IoT varies according to the application where it is implemented; the four basic building blocks for implementing IoT are illustrated in Fig. 1.

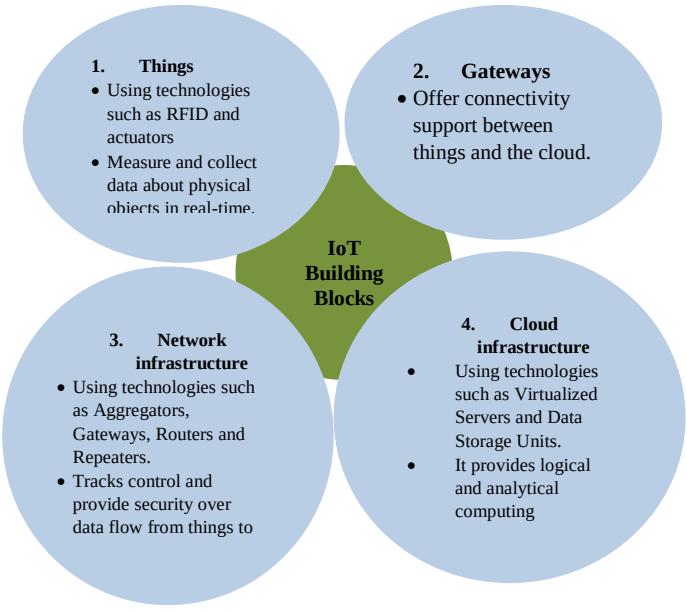

Fig.1: IoT building blocks [27]

Many authors proposed different architecture of IoT, this is shown in Table 1.

Table1. Architecture layers of IoT

Architecture layers	Layers name and its objectives
Three layers [28], [29]	1) Perception layer: connect objects together and capture data using sensors and RFID. 2) Network layer: act as a link between perception layer and IoT hub using gateway, Wi-Fi and hub. 3) Application layer: responsible for the required services. In this layer every application has different requirements.
Four layers [30]	1) Sensing layer: identify, track and collect data from objects using actuators and WSNs and RFID. 2) Network layer: act as a link between cloud and objects. It transmit data to service layer using many protocols such as Zigbee and LoWPAN. 3) Service layer: It is responsible for collecting, exchanging, analyzing and storing data to help in decision making using Service management and analytics. 4) Interface layer: deliver the output smoothly to the user.
Four layers [31]	1) Device layer: capture information from objects using sensors and actuators. 2) Network layer: provide connectivity from/to nodes using internet, WSNs, etc. 3) Service layer: act as a link between application and network layer. 4) Application layer: provides interaction methods for user according to his request using many technologies such as mobile applications.

4. Implementing IoT in Supply chain

4.1. Impacts of applying IoT in Supply Chain

According to literature, IOT has a significant role in improving and enhancing the performance of all functions of SCM. [32] Descried the functions of SCM as production, purchasing, routing, inventory, distribution, location and marketing. All of these functions have the ability to benefit from implementing IoT. These benefits are shown in Fig. 2. The improvement of the warehouse could be measured through the speed to satisfy customers' needs, decreased non value added activities and effective management [33, 34]. So, warehouses should be adapted to achieve this improvement. Implementing IoT in warehousing ensures a positive impact as it could be used to provide a real-time data about all processes and functions. IoT can eliminate manual interferences and make everything connected to provide a vast amount of data from these connections which can be translated to important information to support decisions and improve total performance.

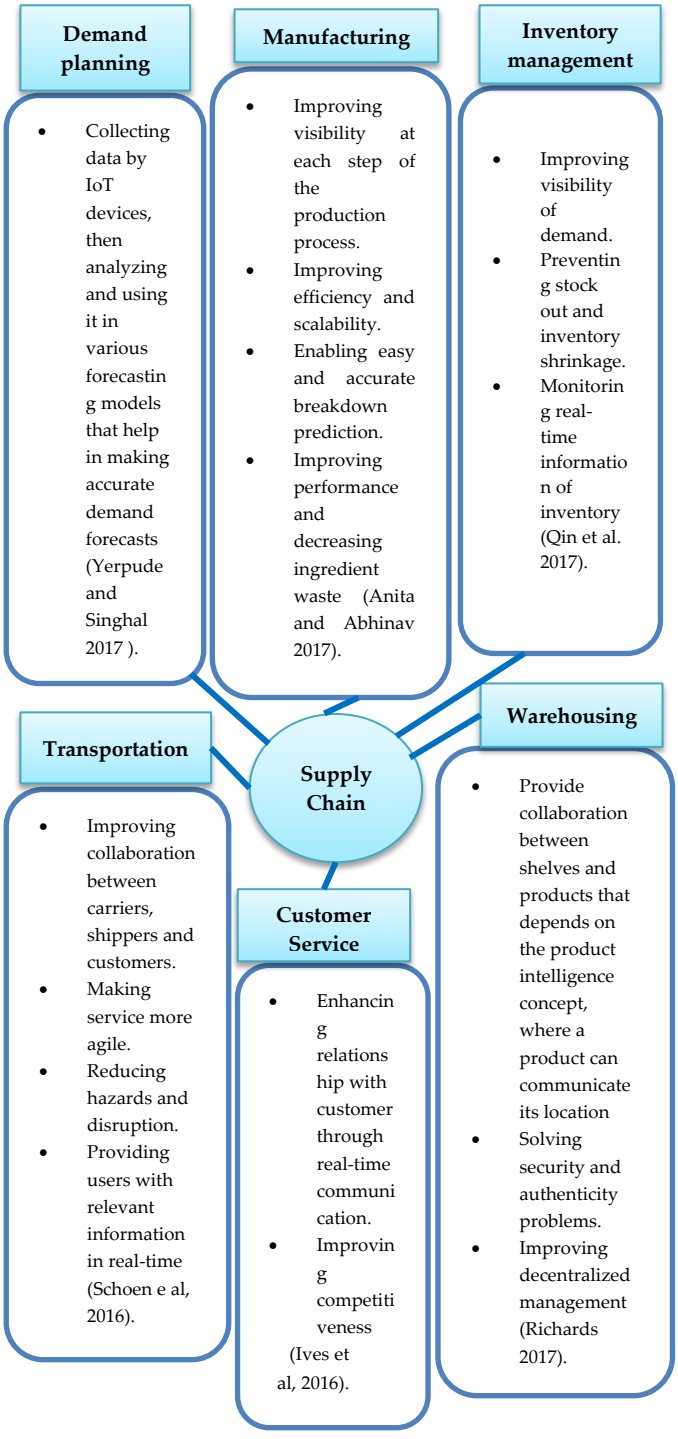

Fig.2: Benefits of implementing IoT in supply chain [18]

4.2. A Framework structure of using IoT in Warehousing

Every product is labeled with a tag that includes information about it such as; product name, production date, expiration date, weight and its location in the warehouse. When the products arrives on the in/out gate of the warehouse these information will be captured immediately through the attached readers on the gats. This helps in providing a real-time data about inventory and prevents both excess inventory and stock-out. Readers attached to the forklift also capture data and share it on the attached screen on the forklift to help the driver knowing the product's type, location and expiry date. When the products are put on the shelves, a message will be sent to the driver on the screen through the readers that attached to shelves.

This message like a confirmation message that this is the correct place of the product and the weight doesn't exceed the shelve weight limits. All of these information captured from sensors and readers are transferred to enterprise applications that process data and convert it to useful information that help in decision making. In the case of order picking, as soon as the order arrives, it appears on the attached screen on the forklift with its location and all information, the driver goes to its location and once the products are captured by the forklift, the readers attached to it give confirmation that it is the correct order. After the picking process ends and the products leaves the warehouse, the level of the inventory is updated immediately. This would make order fulfillment easier, accurate, prevent counterfeiting and make warehouse more efficient.

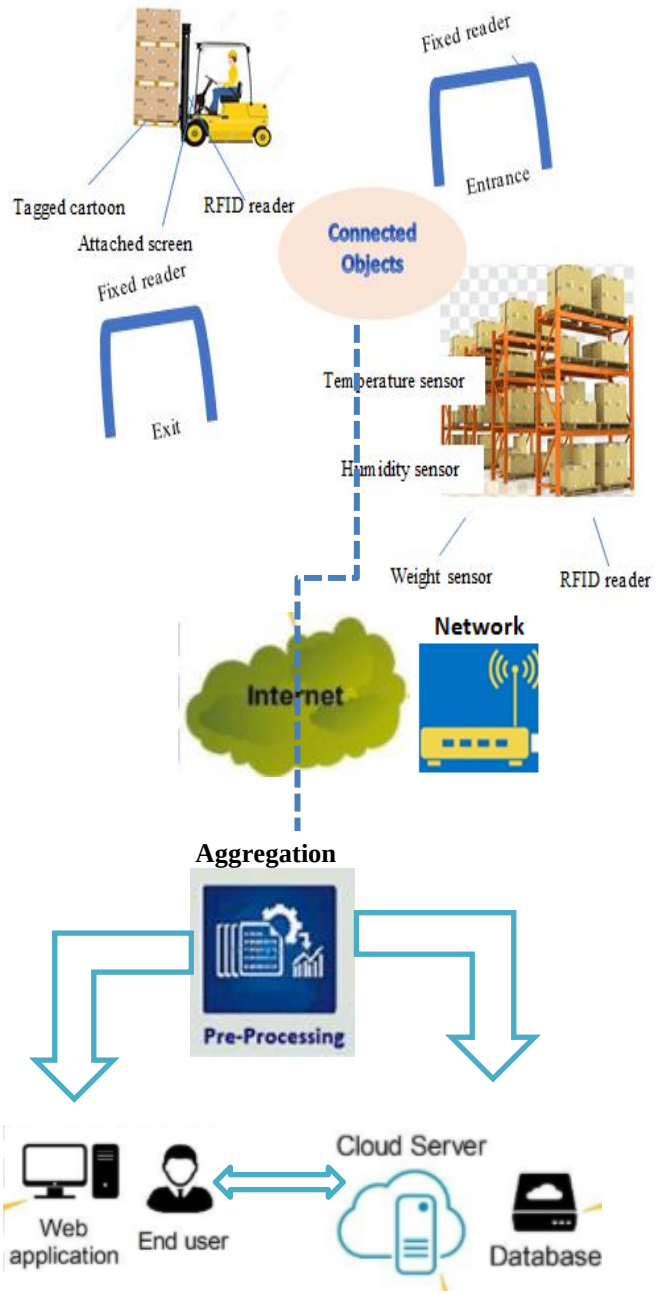

Fig.3: A framework for applying IoT a warehouse

There are a lot of benefits expected from applying this technology such as; ensuring safety of goods and labors, reducing accidents and operational time, increasing efficiency, preventing counterfeiting and theft, increasing reliability and accuracy of picking and packing processes, minimizing the labors number, helping in improving the forecasts due to accurate data, helping in more accurate decision making due to real-time data, and enhancing the

overall performance of the companies. However, companies may face multiple challenges in adopting IoT such as privacy, security and safety as there is a large number of objects connected that generate a vast amount of data and the network can be potentially hacked.

5. Conclusion

IoT is one of the most promising technologies that help in managing, controlling and improving the performance of the supply chain. It can be used for building a smart WMS. This paper summarizes the architecture of IoT and its impact when implemented in the supply chain. We proposed a show how this new technology can help the enterprises to obtain real-time visibility of each item in the warehouse. This proposal can be taken as an effective roadmap for enterprises to improve their warehouses.

Future research should implement this framework on a real case study and develop a simulation model to show the benefits of implementing this proposal and compare the benefits expected from this framework with the actual results.

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